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A BIOLOGICAL EVALUATION OF THE DOUGLAS-FIR TUSSOCK MOTH OUTBREAK IN SOUTHERN IDAHO, 1990

Julie C. Weatherby[1]
K. Andrew Knapp[2]
Brian R. Gardner[3]

ABSTRACT

Approximately 39,400 acres of defoliation were detected during a special Douglas-fir tussock moth aerial survey of the Boise River drainages. In addition, defoliation was detected on Bureau of Land Management and State lands east of Bellevue, on Bureau of Land Management lands within the Owyhee Mountains, near Bald Mountain on the Sawtooth National Forest, in the Manns Creek drainage on the Payette National Forest, and in the Squaw Creek drainage on the Boise National Forest.

The early warning system employed by Forest Pest Management did not detect this outbreak prior to defoliation. Ground surveys of cocoon densities indicate that areas which had been defoliated in 1990 will probably be defoliated again in 1991. The outbreak is undoubtedly more widespread and additional areas of defoliation are expected in 1991.

[1] Entomologist, Forest Pest Management, Intermountain Region, USDA Forest Service.
[2] Biological Technician, Forest Pest Management, Intermountain Region, USDA Forest Service.
[3] Biological Technician, Forest Pest Management, Intermountain Region, USDA Forest Service.

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INTRODUCTION

The Douglas-fir tussock moth, *Orgyia pseudotsugata* McDunnough (DFTM), is a serious defoliator of Douglas-fir and true firs in western North America. Populations cycle periodically, rapidly increasing from endemic to outbreak levels. Outbreak cycles usually last 3 to 4 years before the population collapses as a result of a combination of mortality factors, including parasites, predators, diseases, and starvation.

Tussock moth populations overwinter in the egg stage. Egg hatch occurs after bud break in late May or early June. Small larvae disperse from egg masses redistributing themselves throughout the forest canopy. Long distance tussock moth population dispersal is usually limited to a distance of approximately 1/4 mile (Wickman et al. 1981). Long distance dispersal is accomplished when small larvae spin down from branches and are passively blown by winds.

Larval stages feed first on new foliage and move to older foliage after the new foliage has been consumed. When populations are extremely dense, trees can be almost completely defoliated in 1 year. Larval feeding occurs over a period of 40 to 60 days. Full-grown larvae seek out pupation sites during late July or August. Pupal cocoons are usually found on the undersides of branches; however, when populations are extremely dense, increasing numbers of larvae seek out other pupation sites such as tree trunks, rocks, fence posts, etc. Pupal cocoons consist of grayish, silken coverings each surrounding a single pupa.

Adult males begin emerging from pupal cocoons in August followed by the emergence of female moths. Male moths are gray-brown to black-brown with a wingspan of approximately 1 inch. Large, plumose antennnae are conspicuous. Female moths are flightless and remain on or near their pupal cocoons for the duration of their lifespan. Females produce a pheromone which attracts males for the purpose of mating. Oviposition of eggs occurs directly on top of the pupal cocoon from which the female emerged. An average egg mass contains 200 eggs.

DFTM defoliation can kill trees. As an example, approximately 39 percent of all trees in heavily defoliated areas in the Blue Mountains of Washington and Oregon were killed during the 1972 DFTM outbreak (Wickman et at. 1981). Similar outbreaks have occurred in California, Idaho, Nevada, Arizona, New Mexico, and British Columbia. Top-kill and growth reduction caused by DFTM defoliation have also been documented.

In southern Idaho, periodic outbreaks have occurred. Tunnock et al. (1985) documented the occurrence of several DFTM outbreaks between 1927 and 1984. Despite these repeated outbreaks, vegetation impacts in these areas have been minimal.

This report documents the results of the 1990 early warning system, special aerial detection surveys and subsequent ground surveys designed to estimate DFTM population densities. Population and defoliation projections are proposed for 1991 along with a brief discussion of suppression alternatives.

EARLY WARNING SYSTEM

Methods: The early warning system is designed to detect population increases 1 to 2 years prior to an outbreak and has been used continuously in southern Idaho since 1982. This system includes

deployment of pheromone-baited traps to detect male moths and larval surveys at sites where trap catches the preceeding year exceeded 40 moths per trap (Sower, personal communication).

Trapping involves deployment of five pheromone-baited traps at each site following the procedures outlined by Daterman et al. (1979). In southern Idaho, trap catch data from 1982 to 1989 exist for 20 permanent sampling sites (Gardner and Weatherby 1990); therefore, these sites were again used as sampling sites for 1990. An additional site was added at Deer Point on the Boise Front. Pheromone-baited trapping was intensified at two of the original sites—the Dewey Peak site on Bureau of Land Management lands in the Owyhee Mountains and the Little Water Gulch site in the Sawtooth National Forest where the 1989 catches exceeded 25 moths per trap. The rationale supporting the selection of this 25-moth threshold has been explained by Thier (1987). At these sites, two additional sets of five traps each were deployed in similar stands located within 1 mile of the original site. The number of male moths captured within each trap was recorded, and the mean moth catch per trap was calculated for each site.

Larval sampling using sequential sampling procedures (Mason 1979) was conducted at the Little Water Gulch and Dewey Peak sites where 1989 trap catches approached the 40-moth threshold. The cumulative number of small larvae recovered at each site was recorded and used to qualify the population.

For the past 4 years, we have evaluated an additional monitoring method developed cooperatively by the USDA Forest Service, Region 5, Forest Pest Management and the University of California to sample the population seeking pupation sites. This method involves selecting ten host trees within each trapping site and nailing two cryptic shelters to opposite sides of the bole of each tree. Data collected included the total number of pupae per shelter, their sex, and the condition of each pupae—either healthy, parasitized, or dead from unknown causes.

Table 1 lists the locations of the sampling sites, the sampling methods used at each site, and the sampling dates.

Results: Annual mean trap catches for all sites are listed in table 2. In 1990, trap catches increased at all sites with the exception of two sites on the Salmon National Forest. The average male moth catch per trap for the 21 sites monitored in 1990 was 50.1 moths. This is a nine-fold increase over the mean trap catch recorded in 1989, and the highest average trap catch recorded during the 9 years when routine trapping has been utilized in southern Idaho. At 16 of the 21 sites trap catches exceeded the 25-moth threshold. Of these 16 sites, only 3 sites had trap catches which averaged less than the 40-moth threshold.

Two major trap catch peaks have occurred since 1980. In 1983, trap catches averaged 37.7 moths per trap while in 1990 the average trap catch was 50.1 moths per trap. Prior to the 1983 peak, while a limited number of trap sites were monitored, trap catches averaged more than 20 moths per trap for at least a 3 year period preceeding the 1983 peak. The 1980 catch of 27.8 moths per trap may have been a warning of imminent population increase and resulting defoliation. Defoliation was first detected in 1981 when 160 acres were mapped in the Owyhee Mountains. The defoliated area increased in 1982 to 4,000 acres and peaked in 1983 with 14,193 acres. This outbreak apparently collapsed between 1983 and 1984. No defoliation was reported between 1984 and 1989. Likewise, the mean trap catches, averaged for all trap sites in southern Idaho, remained low during this period. In 1990, populations exploded and over 39,000 acres of defoliation were detected. Trap catches were extremely high in 1990; but, the early warning system failed to detect an impending

outbreak prior to 1990. Figure 1 illustrates the mean trap catches from 1980 to 1990 along with the acres of defoliation detected during aerial surveys.

The larval sequential sampling scheme employed in 1990 at the Dewey Peak site and the Little Water Gulch site classified populations at both sites as suboutbreak. All eleven of the trees sampled at Dewey Peak were infested while only 7 of the 10 sample trees at Little Water Gulch were infested. Overall results of the sampling efforts—cryptic shelters, pheromone-baited traps and larval sampling—indicate that the Dewey Peak population is more dense than the population at Little Water Gulch.

The 1990 cryptic shelter data are summarized in table 3. Pupal cocoons were found in at least some of the cryptic shelters on 10 of the 17 sites. The mean number of pupal cocoons, averaged for all monitored sites, was .98 cocoons per shelter. The ratio of male to female cocoons was approximately 3.27:1.00.

Cryptic shelter data for the last 4 years are found in table 4. The mean number of cocoons per shelter increased from relatively low levels in 1987 and 1988 to higher levels in 1989 and 1990.

A cursory evaluation of these data suggest that mean cocoon densities of 0 to 0.05 cocoons per cryptic shelter are indicative of endemic population levels. If the cocoon densities average more than 0.05 but less than 0.20 cocoons per shelter and increase by a factor of 3 to 4 times the density found in the previous year, a suboutbreak population may be present. Densities in excess of 0.80 cocoons per shelter are probably only recovered during outbreak situations, and some defoliation should be apparent or anticipated.

Based upon these preliminary results, cryptic shelters strategically placed in historical "hot spots" of defoliation may serve as one more tool in the early warning system. Certainly, if the pheromone traps, cryptic shelters, and subsequent larval sampling procedures indicate increasing populations, an outbreak should be anticipated.

STATUS OF CURRENT OUTBREAK

Aerial Detection Survey

Methods: The annual aerial detection survey of the Boise River drainages was completed by July 13, 1990. No defoliation was detected during the July survey. However, due to numerous reports of defoliation from district personnel, Andy Knapp, biological technician in charge of aerial surveys, resurveyed the area of concern during the third week in August of 1990. Areas of defoliation were sketch mapped, digitized, and plotted on a 1/2-in. to the mile map. It was virtually impossible to accurately plot all areas of heavy defoliation as individual patches. Instead, nearby pockets of defoliation with like intensities were combined into larger polygons.

Results: Approximately 39,400 acres of defoliation were mapped during this special DFTM aerial survey of the Boise River drainages. Pockets of heavy defoliation, not detected during the initial survey, were seen scattered among areas of light and moderate defoliation. Thirty-one percent of the total area (12,023 ac) was classified as lightly defoliated, 24 percent (9,351 ac) as moderately defoliated, and 46 percent (18,004 ac) as heavily defoliated. The areas of heaviest defoliation are concentrated on the Boise and Mountain Home Ranger Districts, Boise National Forest. Figure 2

is a copy of the aerial sketch map showing the locations of heavy, moderate, and low defoliation intensities. This area has been extensively "ground truthed" and in all cases the major defoliator was DFTM.

After discovering DFTM defoliation in the Boise River drainages, several other areas of historic concern were resurveyed. Defoliation was detected on Bureau of Land Management (BLM) and State lands east of Bellevue in Big Dry, Italian, and Sharps Canyons and on BLM lands within the Owhyee Mountains. Minor defoliation was noted during ground surveys near Bald Mountain on the Sawtooth National Forest, in the Manns Creek drainage on the Weiser Ranger District, Payette National Forest, and in the Squaw Creek drainage on the Emmett Ranger District, Boise National Forest. Because these areas are so widely scattered, it is likely that other areas are infested.

Ground Surveys

Methods: Based on observable defoliation, areas of nearly contiguous defoliation in the Boise River drainages were grouped together into 6 survey areas. Figure 3 depicts these areas. On September 20, 1990, field crews completed ground surveys in these areas. In each of the six areas, one plot per map section was located in roaded portions of the areas. Whenever possible plot locations were selected by driving approximately 1/4 mile on system roads into the section. The nearest stand with at least 50 percent host tree stocking, i.e. Douglas-fir and subalpine fir, was selected. Twenty host trees, 10 to 120 feet tall with foliated branches within reach of the ground, were sampled at each site. From each host, 3 branches displaying evidence of 1990 growth flushes were arbitrarily selected and the distal 18 in. of each branch was inspected for presence of DFTM pupal cocoons. The total number of pupal cocoons found on each branch, along with the number of cocoons covered with egg masses were recorded. Cocoon densities were reported as numbers of cocoons per 1,000 in.^{2} of foliage (3, 18-in. branches equal approximately 100 in.^{2} of foliage).

Tree species and a visual estimate of defoliation were also recorded for each sample tree. Trees with less than 25 percent defoliation were classified as lightly defoliated, trees with 25 to 50 percent defoliation were moderately defoliated, and trees with defoliation in excess of 50 percent were recorded as heavily defoliated.

Results: Eighty-eight plots were sampled in the six areas of defoliation. The average cocoon density for all 88 plots was 1.01 cocoons per 1,000 in.^{2} of foliage. Cocoons with egg masses accounted for 44 percent of the average number of cocoons detected during the ground survey.

To predict 1991 larval populations and defoliation, we used a regression equation developed by Mason et al. (unpublished) for use on pre-outbreak populations ($Y = 1.07 + 63.9X$, Y = predicted early larval density per 1,000 in.^{2} of foliage, X = cocoon density per 1,000 in.^{2} of foliage). We understand that this equation is intended for use on pre-outbreak populations and expect that predictions will most probably be over-estimations. The predicted larval population averaged for all sample plots is 65.24 larvae per 1,000 in.^{2} of foliage. This population level can be expected to cause moderate defoliation. Table 5 summarizes this information for areas 1 through 6.

Within area 1, there are 2,550 acres of defoliation located south of the South Fork of the Boise River in the Abbot Gulch, Virginia Gulch, and West Fork Kelley Creek drainages. During the aerial detection survey, eight pockets of light defoliation were sketch mapped in predominantly Douglas-fir stands. Ground crews installed eight plots within the area. Populations were detected

at four of the eight plots. The average pupal density for all plots in area 1 was 0.78 cocoons per 1,000 in.^{2} of foliage (s=1.42). If only infested plots are included in the mean, the average pupal density was 1.55 cocoons per 1,000 in.^{2} of foliage (s=1.76). Stand defoliation within the sampling plots was classified as non-defoliated to lightly defoliated. Barring a collapse in the population, mean larval densities in 1991 may reach levels ranging from 52 to 100 larvae per 1,000 in.^{2} of foliage. These predicted population levels are reported to cause moderate to heavy defoliation.

Within area 2, there are 2,284 acres of defoliation located in the Marsh Creek, Shake Creek and Willow Creek drainages. The aerial survey map shows only light defoliation within this area. Cocoon sampling was performed at five sites and populations were detected at two of these sites. Populations were relatively low averaging 0.12 cocoons per 1,000 in.^{2} of foliage when all sites are included in the calculations and 0.30 cocoons per 1,000 in.^{2} when only the infested sites were averaged. In infested areas, 1991 larval populations are predicted to average 20 larvae per 1,000 in.^{2} of foliage. Therefore, low to moderate defoliation should be expected in 1991.

Within area 3, there are 2,948 acres of defoliation located near Rocky Bar. Area 3 was not sampled.

Area 4 is the largest contiguous block of defoliation detected from the air. This area encompasses approximately 31,334 acres in the Roaring River, Lost Man Creek, Trinity Creek and Phifer Creek drainages. Cocoon densities were sampled on 54 plots. Densities ranged from 0 to 5.6 with a mean of 1.1 cocoons per 1,000 in.^{2} of foliage. Cocoon densities found in areas displaying similar defoliation intensities were 0.3, 1.0, and 2.8 cocoons per 1,000 in.^{2} in the no defoliation, light defoliation, and moderate defoliation classes, respectively. Only 1 of the 54 sample plots was classified as heavily defoliated, and the number of cocoons per 1,000 in.^{2} averaged 3.8. Larval populations in 1991 predicted from the 1990 cocoon densities could reach as high as 243.9 larvae per 1,000 in.^{2} of foliage. We expect the larval population to decline in 1991 in the areas which have been heavily defoliated in 1990. However, in the infested areas which displayed little or no defoliation in 1990, populations may increase. In these areas, defoliation ranging from light to extremely heavy can be expected in 1991.

Within area 5, there are 2,088 acres of defoliation located north and south of the middle fork of the Boise River near Atlanta. Much of the area south of Atlanta has been heavily defoliated. Seventeen plots were sampled in the area and populations were detected at nine of these plots. The mean cocoon density per 1,000 in.^{2} of foliage averaged for all plots was 1.0 (s=1.9). The highest cocoon density found in any of the sampled areas was detected in a plot within area 5. The mean predicted larval population for 1991 is 63.3 larvae per 1,000 in.^{2} of foliage. Defoliation levels in 1991 are expected to be variable; however, based on the predicted larval density, moderate and heavy levels should be anticipated. We expect 1991 populations to decline in the areas most heavily infested in 1990. Other areas will most likely display increased levels of defoliation.

Several pockets of defoliation were detected near Grand Mountain and these pockets have been grouped together into area 6 which encompasses approximately 1,276 acres of defoliation. Four plots were sampled and populations were detected at all of the plots. The mean number of cocoons per 1,000 in.^{2} of foliage averaged 1.13 and ranged from 0.3 to 1.7. The 1991 larval populations predicted from 1990 cocoon samples can be expected to average 72.95 larvae per 1,000 in.^{2} of foliage. We suspect that defoliation will increase throughout the area in 1991.

DISCUSSION

Based upon the information gathered in 1990, the current DFTM outbreak will probably continue for at least 1 more year. The outbreak is undoubtedly more widespread and additional areas of defoliation will probably become apparent. All evidence indicates that areas which have been heavily defoliated in 1990 may be defoliated again in 1991 perhaps at lesser intensities. More severe defoliation is likely in areas which were not severely defoliated in 1990. Some mortality and top-kill should be anticipated. Trees defoliated 90 percent or more and concentrated in patches have the highest probability of dying. Presently, we have not experienced this level of defoliation. Understory trees will be most heavily impacted. Mortality caused by DFTM defoliation should be less severe in the dominant and co-dominant classes.

Most areas discussed in this report have active infestations of Douglas-fir beetle and western balsam bark beetle (Figure 4). Likewise, in grand fir stands, not discussed in detail within this report, fir engraver activity is at epidemic levels. We are concerned that DFTM defoliation may exacerbate the bark beetle outbreaks. If this occurs, the larger diameter intermediates, co-dominants, and dominants are probably at greatest risk. Increases in bark beetle activity have been reported during and following other DFTM outbreaks (Wickman 1978, Buckhorn unpubl.). Initially, bark beetle caused mortality occurred in trees which have been heavily defoliated (80 to 90 percent). Following the initiation stage, beetles attacked trees indiscriminately through most of the defoliation categories. Therefore, after the DFTM outbreak subsided, 50 percent of the total bark beetle caused mortality occurred in trees defoliated from 5 to 35 percent. Data from similar outbreaks indicates that "only trees severely defoliated (80 percent or more) appear to have a high probability of being attacked by bark beetles the first 1 or 2 years after defoliation takes place; but then, continued bark beetle activity is dependent on other environmental factors" (Wickman 1978).

Unfortunately, the early warning system did not detect this outbreak. In order to successfully suppress DFTM populations prior to experiencing defoliation, the land manager needs techniques which will accurately detect sub-outbreak populations. Otherwise, the outbreak cycles so rapidly that populations may actually be declining by the time the land manager is able to implement a suppression project. We will be spending considerably more time in FY91 trying to expand on our early warning system and to refine the techniques.

MANAGEMENT ALTERNATIVES

Management alternatives for dealing with DFTM outbreaks follow:

No action alternative - Under the no action alternative, the outbreak would be allowed to run its course. Usually this would be a 3 to 4 year period. Because nothing has been done to disturb the complex of natural controlling agents, the population would collapse when the controlling agents are able to reduce the population to endemic levels.

Trees which are defoliated repetitively and retain less than 10 percent of their foliage have a high probability of dying. Currently, we have not experienced this level of defoliation except in the understory. Without suppression, additional defoliation will occur in 1991, and it is possible that scattered pockets of severe defoliation will occur.

Douglas-fir beetle and western balsam bark beetle will continue to cause mortality in the area. Defoliation is likely to increase the susceptibility of trees to bark beetle attack.

The advantages of this alternative are that no insecticides are introduced into the ecosystem, and the populations remain under natural control. In addition, reductions in forest cover may increase the regeneration potentials of seral, shade intolerant species and increase water yield and game forage.

Disadvantages of this alternative include increases in tree mortality which may result in reduced timber values, recreational usage, and visual quality.

Salvage Alternative - Under this alternative, trees that are expected to die would be removed with the overall objectives of improving the vigor of the leave trees and recovering some value from the salvaged trees. These activities will have little or no effect on the DFTM populations. They may help to reduce additional mortality associated with subsequent bark beetle outbreaks. Refer to the discussion section of this report to assist in determining which trees should be removed.

The advantages of this alternative include recovery of some monetary value from dead and dying trees, improvement of stand health, and elimination of hazards associated with dead trees.

Disadvantages include the added cost of planning and implementing a salvage sale.

Direct Suppression Alternative - Direct suppression of DFTM populations on large blocks of forest lands is best accomplished through aerial applications of either chemical or biological insecticides.

Aerial application of chemical insecticides - Aerial application of chemical insecticides are effective in reducing DFTM population to suboutbreak levels. Applications are most effective if large contiguous blocks can be treated. Applications are usually made in June after larval dispersal. Registered insecticides include acephate, carbaryl, and dimilin. Chemical insecticides are usually less selective than the registered biological insecticides; therefore, their use must be carefully evaluated in terms of other environmental constraints.

Advantages of chemical applications include rapid knock down of DFTM populations and protection of current foliage, thereby reducing subsequent tree mortality.

Disadvantages associated with this alternative include the introduction of a chemical insecticide into the ecosystem with some disruption to the natural balance, and the costs incurred in planning and implementing a chemical insecticide project.

Aerial application of biological insecticides - Biological insecticides which are registered for suppression of DFTM include *Bacillus thuringiensis*, *B.t.*, and a nuclear polyhedrosis virus, TM Biocontrol-1™. The virus is specific to DFTM while *B.t.* is toxic to most lepidopterous insects. Biological insecticides require careful timing in order to effectively reduce populations.

Advantages of biological applications include suppression of DFTM populations with minor environmental consequences.

A disadvantage of this alternative over the chemical alternative is that foliage protection during the year of the application is usually less effective.

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Table 1.—*Location and sampling methods utilized during the 1990 Douglas-fir tussock moth early warning survey in southern Idaho.*

Plot	Location			Larval Samples	Cryptic Shelters	Pheromone Traps		
	T.	R.	Sec.	Date	Date Checked	#	Date Instal.	Date Retrv.
Boise NF								
Bear Creek	4N	10E	7	*	10/24	5	7/30	10/24
Skunk Creek	12N	4E	14	*	10/18	5	8/02	10/18
Deer Point	5N	3E	29	*	*	5	7/30	10/30
Payette NF								
Adams Creek	14N	6W	23	*	10/25	5	7/31	10/25
Barinaga Corral	20N	2W	23	*	*	5	8/02	10/19
Bear Saddle	15N	5W	31	*	*	5	7/31	10/25
E. Fk. Brownlee	16N	4W	3	*	10/19	5	7/31	10/19
Fourbit Creek	13N	2E	7	*	10/19	5	7/31	10/19
McDowell Trail	17N	2W	17	*	10/25	5	8/02	10/25
Olive Creek	17N	2W	7	*	*	5	8/02	10/25
Seid Creek	16N	4W	21	*	10/19	5	7/31	10/19
Stacy Creek	14N	6W	14	*	10/25	5	7/31	10/25
Salmon NF								
Colson Creek	23N	16E	12	*	*	5	8/07	10/12
Lick Creek	26N	22E	32	*	*	5	8/07	10/12
Sawtooth NF								
Little Water Gulch	3N	12E	7	6/20	10/24	15	7/30	10/24
Virginia Gulch	3N	11E	9	*	10/24	5	7/30	10/24
Idaho State Lands								
Sharps Canyon	2N	19E	36	*	10/16	15	8/09	10/16
BLM Lands								
Dewey Peak	6S	4W	3	6/21	10/29	15	7/31	10/29
Mill Creek	8S	5W	12	*	10/30	5	7/31	10/30
New York Summit	4S	3W	32	*	10/29	5	7/31	10/29
So. Fk. Boulder Ck.	8S	5W	24	*	10/30	5	7/31	10/30

* Not sampled.

Table 2.—*Summary of male Douglas-fir tussock moths caught in pheromone-baited sticky traps distributed in southern Idaho, 1981 to 1990.*

Plot	Location			Mean Number of Male Douglas-fir Tussock Moths/Trap by Year									
	T.	R.	Sec.	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Boise NF													
Bear Creek	4N	10E	7	*	0.0	32.8	0.4	0.0	1.2	1.4	0.6	0.2	31.6
Skunk Creek	12N	4E	14	0.2	0.6	29.0	0.0	1.0	1.2	0.2	0.2	0.0	5.3
Deer Point	5N	3E	29	*	*	*	*	*	*	*	*	*	65.6
Payette NF													
Adams Creek	14N	6W	23	*	53.6	39.6	7.8	4.0	17.6	8.8	1.8	2.6	78.6
Barinaga Corral	20N	2W	23	*	*	44.2	0.4	2.8	4.0	2.0	0.0	1.0	9.6
Bear Saddle	15N	5W	31	*	15.2	44.0	1.0	0.2	0.2	0.4	0.0	0.0	84.8
E. Fk. Brownlee	16N	4W	3	*	61.2	50.6	2.6	3.4	27.0	6.0	0.2	0.4	56.8
Fourbit Creek	13N	2E	7	*	49.8	42.8	*	4.8	30.4	2.0	2.2	1.2	37.0
McDowell Trail	17N	2W	17	*	*	35.8	5.0	6.8	24.6	1.2	0.0	0.0	26.8
Olive Creek	17N	2W	7	*	36.8	51.2	14.6	10.5	46.8	9.8	3.2	0.5	19.4
Seid Creek	16N	4W	21	*	*	17.4	11.2	*	27.2	4.8	1.6	0.4	51.6
Stacy Creek	14N	6W	14	*	*	42.8	18.0	8.8	3.8	5.0	0.0	0.4	63.2
Salmon NF													
Colson Creek	23N	16E	12	*	15.2	39.0	3.2	*	7.2	5.2	14.0	0.6	0.4
Lick Creek	26N	22E	32	*	7.6	38.4	0.6	*	6.0	0.6	28.5	0.6	0.4
Sawtooth NF													
Little Water Gulch	3N	12E	7	3.8	13.6	27.0	17.2	0.0	34.6	26.6	4.0	32.5	102.0
Virginia Gulch	3N	11E	9	0.6	2.0	26.8	1.8	0.0	4.8	6.8	2.6	0.4	58.6
Idaho State Lands													
Sharps Canyon	2N	19E	36	19.4	16.2	41.2	1.3	5.2	22.6	8.4	36.4	9.2	53.2
BLM Lands													
Dewey Peak	6S	4W	3	64.0	*	*	15.0	1.6	33.7	38.6	47.0	36.3	80.4
Mill Creek	8S	5W	12	47.6	*	*	6.6	0.0	0.4	0.0	0.2	0.2	53.0
New York Summit	4S	3W	32	*	*	*	0.0	*	1.8	3.8	15.0	12.6	71.8
So. Fk. Boulder Ck.	8S	5W	24	*	*	*	0.7	0.2	1.8	0.2	0.8	2.2	96.8
Mean				22.6	22.7	37.7	5.7	3.1	14.9	6.6	7.8	5.1	50.1

* Not sampled.

Table 3.—*Mean number of healthy female and male cocoons and the mean number of failed cocoons recovered per cryptic shelter at sites scattered across southern Idaho, 1990.*

Plot	No. Shelters	Mean No. Pupal Cocoons/Shelter		
		Females	Males	Failed
Boise NF				
Bear Creek	20	0.05	0.00	0.00
Skunk Creek	20	0.00	0.00	0.00
Deer Point	0	*	*	*
Payette NF				
Adams Creek	16	0.38	0.81	0.31
Barinaga Corral	0	*	*	*
Bear Saddle	0	*	*	*
E. Fk. Brownlee	20	0.05	0.15	0.00
Fourbit Creek	20	0.00	0.00	0.00
McDowell Trail	20	0.00	0.00	0.00
Olive Creek	0	*	*	*
Seid Creek	20	0.00	0.00	0.00
Stacy Creek	20	0.35	0.40	0.15
Salmon NF				
Colson Creek	20	0.00	0.00	0.00
Lick Creek	20	0.00	0.00	0.00
Sawtooth NF				
Little Water Gulch	20	0.15	0.75	0.00
Virginia Gulch	20	0.00	0.00	0.00
Idaho State Lands				
Sharps Canyon	20	0.00	0.85	0.00
BLM Lands				
Dewey Peak	20	2.40	8.75	0.20
Mill Creek	20	0.00	0.15	0.00
New York Summit	20	0.20	0.40	0.00
So. Fk. Boulder Ck.	20	0.10	0.05	0.00
Mean		0.22	0.72	0.04
s		0.58	2.09	0.09

* Not sampled.

Table 4.—*Mean number of cocoons recovered per cryptic shelter at sites scattered across southern Idaho, 1987 to 1990.*

Plot	Mean No. Pupal Cocoons/Shelter			
	1987	1988	1989	1990
Boise NF				
Bear Creek	0.00	0.00	0.10	0.05
Skunk Creek	0.00	0.00	0.00	0.00
Deer Point	*	*	*	*
Payette NF				
Adams Creek	0.00	0.10	0.17	1.50
Barinaga Corral	0.00	0.00	0.05	*
Bear Saddle	0.00	0.00	0.25	*
E. Fk. Brownlee	0.05	0.00	0.10	0.20
Fourbit Creek	0.05	0.00	0.00	0.00
McDowell Trail	0.00	0.00	0.00	0.00
Olive Creek	0.00	0.00	0.00	*
Seid Creek	0.00	0.00	0.00	0.00
Stacy Creek	0.00	0.10	0.15	0.90
Salmon NF				
Colson Creek	0.05	0.05	0.18	0.00
Lick Creek	0.00	0.00	0.00	0.00
Sawtooth NF				
Little Water Gulch	0.20	0.20	0.20	0.90
Virginia Gulch	0.10	0.00	0.00	0.00
Idaho State Lands				
Sharps Canyon	0.05	0.00	0.20	0.85
BLM Lands				
Dewey Peak	0.25	0.30	1.20	11.35
Mill Creek	0.00	0.00	0.05	0.15
New York Summit	0.00	0.00	0.20	0.60
So. Fk. Boulder Ck.	0.00	0.00	0.00	0.15
Mean	0.04	0.04	0.14	0.98
s	0.07	0.08	0.26	2.71

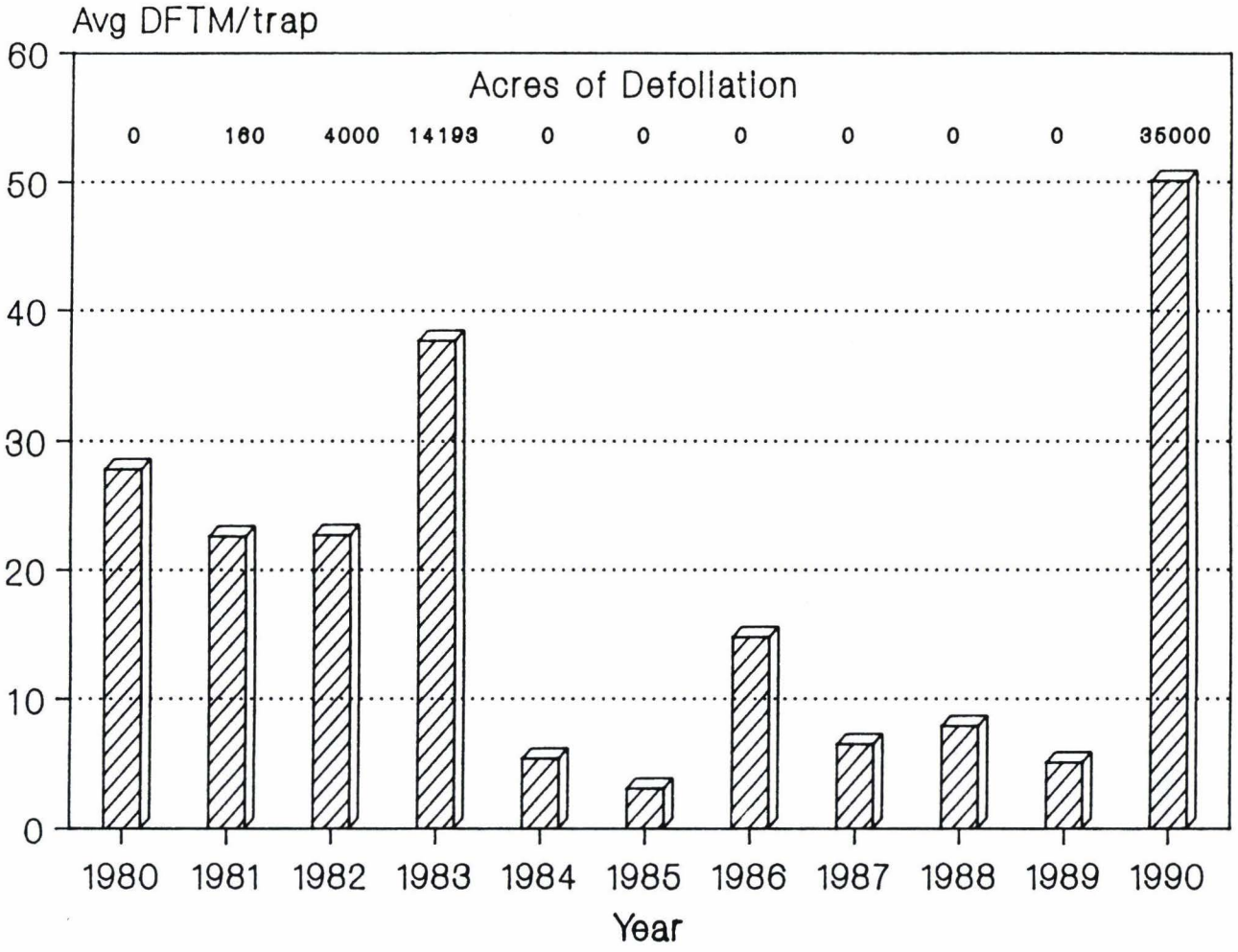
* Not sampled.

Table 5.—*Mean number of cocoons and egg masses per 1000 in^2 of foliage observed in 1990 and the mean number of larvae per 1000 in^2 of foliage predicted for the 6 areas of defoliation within the Boise River drainages.*

Area	No. Plots		1990		1991
			No. Cocoons Observed	No. Egg Masses Observed	No. Larvae Predicted
Area 1	8				
		mean	0.78	0.39	51.66
		s	1.42	0.76	90.28
Area 2	5				
		mean	0.12	0.00	8.10
		s	0.18	0.00	11.97
Area 3	*				
Area 4	54				
		mean	1.10	0.41	72.80
		s	1.20	0.54	79.20
Area 5	17				
		mean	1.00	0.48	63.30
		s	1.90	1.08	119.70
Area 6	4				
		mean	1.13	0.43	72.95
		s	0.59	0.29	37.78
Total	88				
		mean	1.01	0.44	65.24

* Not sampled.

Figure 1.—Mean trap catches from 1980 to 1990 and the acres of defoliation detected during aerial surveys throughout southern Idaho.



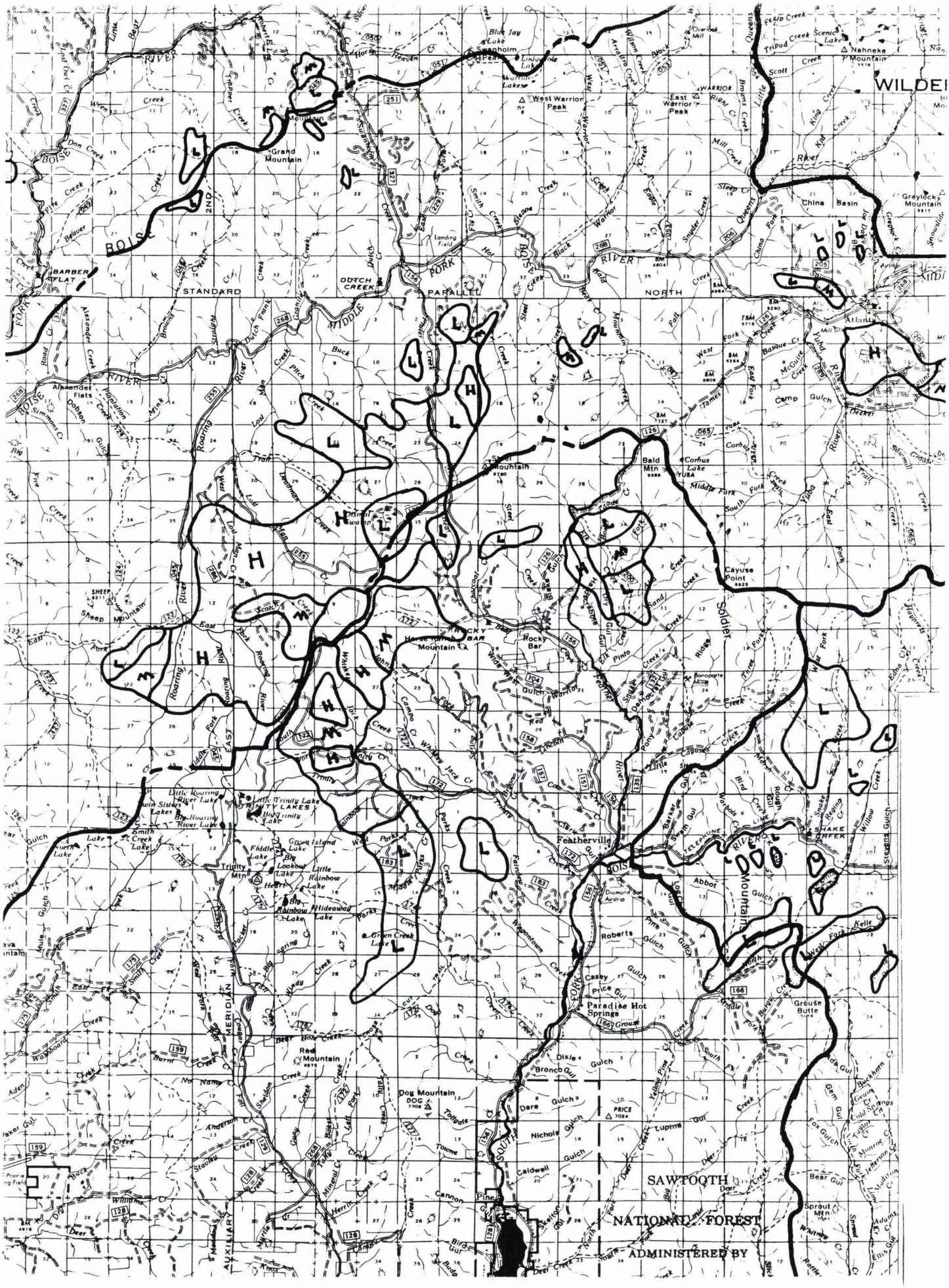


Figure 2.—1990 aerial sketch map showing the locations of heavy (H), moderate (M), and light (L) defoliation intensities on the Boise and Mountain Home Ranger Districts.

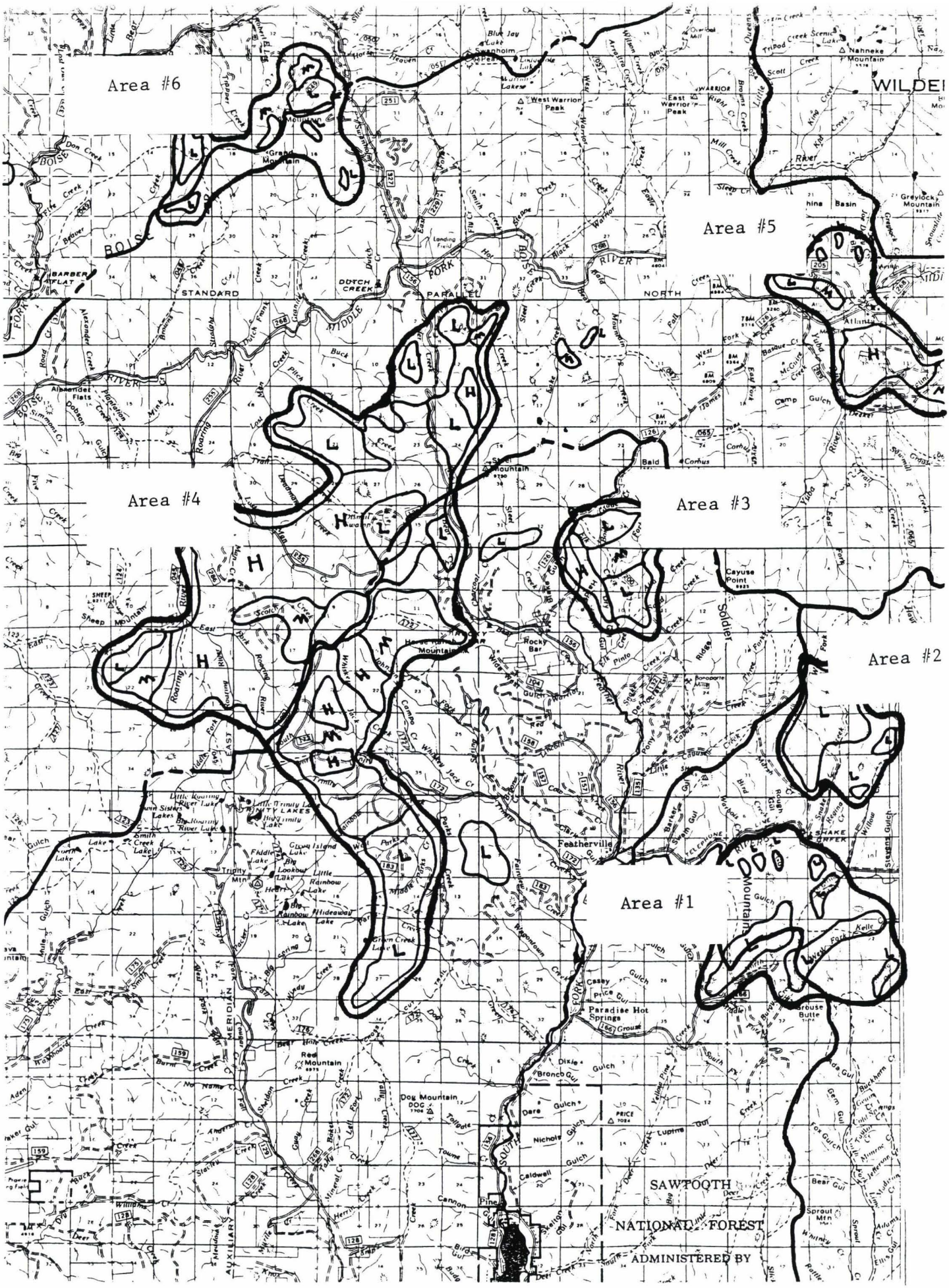


Figure 3.—Defoliation areas delineated for purposes of ground surveys.

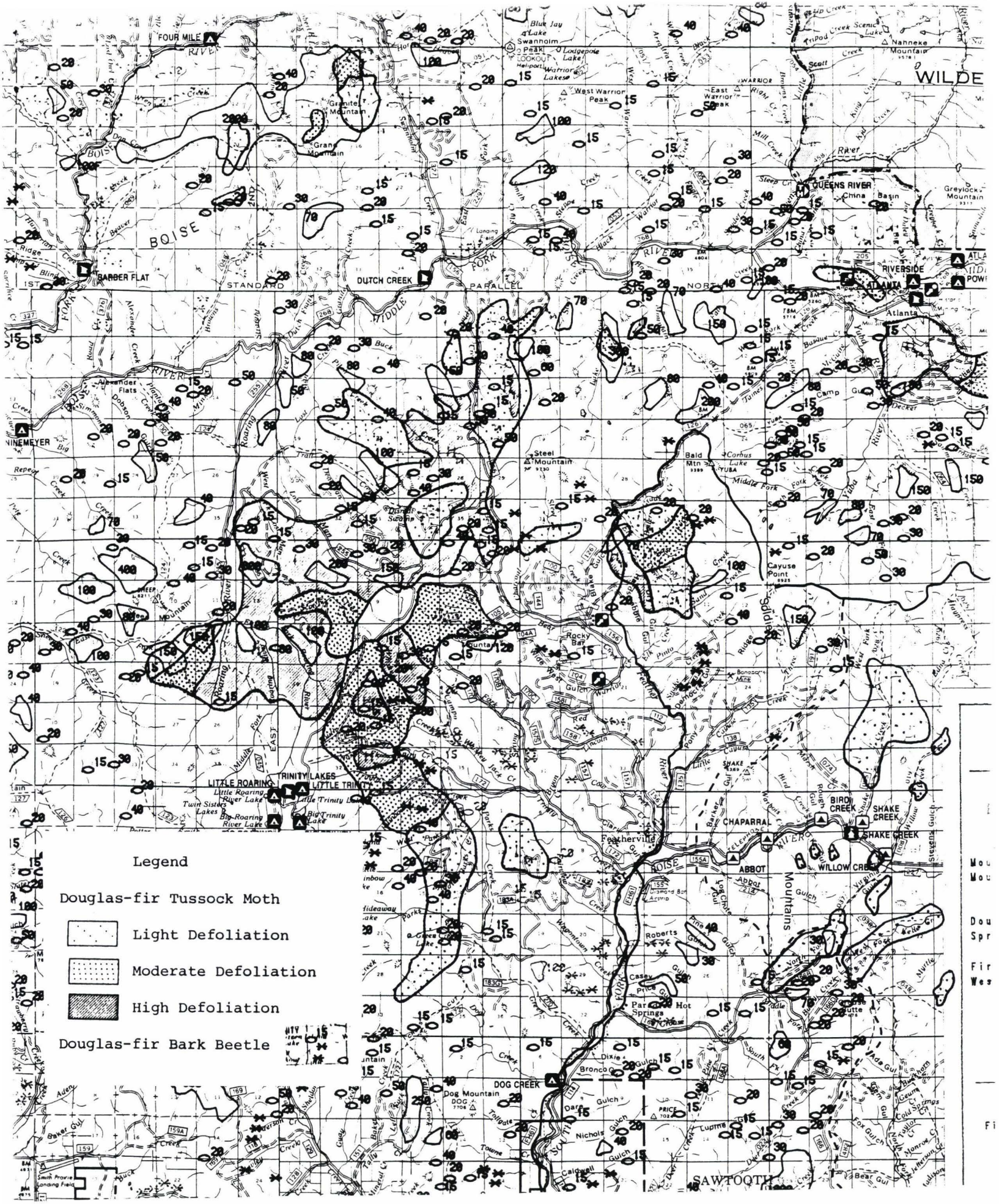


Figure 4.—Douglas-fir beetle infestations located near the areas of defoliation caused by Douglas-fir tussock moth.